FINAL REPORT

LABORATORY: Materials

COLUMBIUM DUCTILITY

ABSTRACT

This test was conducted to determine if D-43 and Cb-752 columbium alloys (LB2 coated and bare) exhibit a severe loss in ductility at 1400F.

The Columbium Evaluation Program presently being conducted at McDonnell includes testing at temperatures ranging from room to 2700F. Results from this testing indicate that the ductility of Cb-752 is lower in the 1200 to 1800F range than at room temperature or in the 2200F and above range. This loss in ductility has not been great enough to indicate that the material is brittle; however, the test temperatures being investigated have not included intermediate temperatures between 1200 and 1800F. Therefore, it is necessary to determine the ductility of the columbium alloys at temperatures in the 1300 to 1600F range.

Mechanical properties data obtained during this investigation indicate that there is no severe loss in ductility in either the Cb-752 or D-43 columbium alloy specimens in the range from 1300 to 1600F. Bend tests performed in the same temperature range, however, resulted in severe surface cracking or fracturing of the specimens during the test.

Based on the results of tests at 1400F, it is concluded that the uniaxial ductility of Cb-752 and D-43 columbium alloys does not undergo a substantial decrease at 1400F; however, the biaxial ductility appears to decrease at this temperature.

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1. INTRODUCTION

This test was conducted to determine if D-43 and Cb-752 columbium alloys exhibit a severe loss in ductility at 1400F.

The Columbium Evaluation Program presently being conducted at McDonnell includes testing at temperatures ranging from room temperature to 2700F. Results from this testing indicate that the ductility of Cb-752 is lower in the 1200 to 1800F range than at room temperature or in the 2200F and above range. This loss in ductility has not been great enough to indicate that the material is brittle; however, the test temperatures being investigated do not include intermediate temperatures between 1200 and 1800F. Therefore it is necessary to determine the ductility of the columbium alloys at temperatures in the range of 1300 to 1600F

Elevated temperature mechanical properties and bend tests were conducted by the McDonnell Metallurgical Laboratory during the period 17 January 1966 through 4 March 1966.

2. SPECIMEN PREPARATION

Tension and bend specimens as listed in Table 1 on page 4 were prepared for this test. The specimens were fabricated from 0.018 inch thick Cb-752 and D-43 columbium alloys obtained for the Columbium Evaluation Program (TR513-367 and addendums). The tensile specimens were fabricated with the final rolling direction of the material perpendicular to the specimen length, and the bend specimens were fabricated with the final rolling direction of the material perpendicular to the 2.00 inch dimension. The edges of the coated specimens were rounded to a radius of one-half the material thickness (0.009 inches) prior to coating.

The coated specimens were R-2coated per McDonnell PS 13156, using the 1700F, two hour diffusion cycle.

3. TEST PROCEDURE

Three coated and three bare tensile specimens fabricated from each of the two alloys were tested at 1300, 1400, 1500 and 1600F and the ultimate tensile strength, yield strength (0.2% offset) and percent of elongation in 1 inch determined. The tests were conducted at a loading rate of 0.050 inches per minute throughout testing. The elevated temperature tests were performed at 5×10^{-5} torr or less, and the specimens were held at test temperature 15 minutes prior to load application.

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3. TEST PROCEDURE (continued)

Using Hot Form Bend Equipment HFE272-1H9-501 TD with a female die opening of 2R plus 2.5t, where R is the mandrel radius and t is the material thickness, three coated and three bare bend specimens were formed in air at selected temperatures between 1300 and 1600F. The specimens were bent through an angle of 120° at a punch speed of 1 inch per minute. The mandrel radius employed during the bend test was 0.047 inches. Specimens were held at the test temperature 15 minutes prior to bending. In the case of those specimens which fractured during the forming process, the approximate bend angle at fracture was noted.

4. TEST RESULTS

Tables 2 and 3 on pages 5 through 8 present the mechanical properties data obtained on the coated and bare Cb-752 and D-43 columbium alloys and Tables 4 and 5 on pages 9 and 10 present the bend test data gathered during this investigation. Figures 1,2,3, and 4 on pages 11, 12, 13, and 14 are photographs of typical bend and tensile specimens after testing. The average mechanical properties are presented graphically in Figure 5, on page 15.

4. DISCUSSION OF RESULTS

The mechanical properties data indicate that there is no severe loss in ductility of either the Cb-752 or D-43 columbium alloy specimens in the range from 1300 to 1600F. The bend test data obtained in the same temperature range shows that the bend test specimens either underwent severe surface cracking or fractured during the 120 degree bend test. A heavy oxide film formed on all of the uncoated bend specimens during the elevated temperature tests, and this may have had adverse effects on the bend properties of the material.

The minimum room temperature mechanical properties required for Cb-752 columbium alloy sheet per MMS -183 are as follows: Ftu-75,000 psi, Fty 60,000 psi, elongation - 15 percent in 1.00 inch. Bend test requirements as defined in paragraph 3.5.2 of MMS-183 or as follows: The bend transition temperature shall not exceed 70F when defined as the minimum temperature at which a specimen .075 inches and under may be bent through a 90 degree angle over a 1T radius without cracking.

5. CONCLUSIONS

Based on the results of these tests, it is concluded that the uniaxial ductility of Cb-752 and D-43 columbium alloys does not undergo a substantial decrease at 1400F; however, the biaxial ductility appears to decrease at this temperature.

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TABLE 1

TEST SPECIMENS

Quantity	Alloy	Type	Configuration
12	Cb-752	Bare tensile	McDonnell Std. 6M117-1
12	Cb-752	Coated tensile	
12	D-43	Bare tensile	
12	D-43	Coated tensile	
12	Cb-752	Bare bend	0.018in.x 0.50in. x 2.00in.
12	Cb-752	Coated bend	
12	D-43	Bare bend	
12	D-43	Coated bend	

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TABLE 2

MECHANICAL PROPERTIES OF BARE AND LB-2 COATED Cb-752 COLUMBIUM ALLOY

Specimen Number	Test Temp. (°F)	Fty (Ksi)	Ftu (Ksi)	Percent Elongation in 1.00 inch
1 - Bare	1300	36.0	55.5	13
2		40.0	56.5	13
3		39.5	55.5	12.5
Average		38.5	55.8	12.8
4 Bare	1400	37.0	55.5	12.5
5		37.0	54.5	12
6		36.5	54.5	13
Average		36.8	54.8	12.5
7 Bare	1500	36.0	54.0	14
8		35.5	55.0	10
9		36.0	55.0	12
Average		35.8	54.6	12
10 Bare	1600	34.5	51.5	15
11		34.0	53.0	12
12		36.5	53.5	14
Average		35.0	52.6	13.6
5 - Coated	1300	38.5	51.0	6
7		38.0	54.5	6.5
8		38.0	50.5	8
Average		37.0	52.0	7

(continued)

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TABLE 2 - (continued)

Specimen Number	Test Temp. (°F)	Fty (Ksi)	Ftu (Ksi)	Percent Elongation in 1.00 inch
9 - Coated	1400	36.0	51.0	8
10		33.5	50.5	9
11		39.0	52.2	8
Average		36.2	51.2	8.3
12 Coated	1500	38.0	49.5	8
13		33.5	52.5	8
17		34.5	52.0	7
Average		35.3	51.3	7.6
15 Coated	1600	35.1	49.5	15
20		30.0	50.0	13
21		32.5	50.0	15

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TABLE 3

MECHANICAL PROPERTIES OF BARE AND LB-2 COATED D-43 COLUMBIUM ALLOY

Specimen Number	Test Temp (°F)	Fty (ksi)	Ftu (Ksi)	Percent Elongation in 1.00 inch
1 - Bare	1300	47.0	59.5	8
2		46.5	58.5	8.5
3		46.5	58.5	10
Average		46.6	58.8	8.8
4 Bare	1400	47.5	57.0	9
5		47.5	58.5	9
6		47.5	58.0	9.5
Average		47.5	58.0	9.5
7 Bare	1500	46.5	56.0	10
8		43.5	54.0	7.5
9		46.5	54.5	9
Average		45.5	54.8	8.8
10 Bare	1600	42.0	52.0	9
11		41.0	52.0	9
12		40.5	52.0	8
Average		41.1	52.0	8.6
1 - Coated	1300	39.0	49.5	8
2		39.5	50.0	7
3		40.5	50.0	6
Average		39.6	49.8	7

(continued)

TABLE 3 (continued)

Specimen Number	Test Temp (°F)	Fty (ksi)	Ftu (ksi)	Percent Elongation in 1.00 inch
4 - Coated	1400	38.5	47.0	7
5		39.0	47.5	5
6		41.0	48.0	6
Average		39.5	47.5	6
7 Coated	1500	40.0	48.0	8
8		40.0	47.0	8
9		39.5	46.5	8
Average		39.8	47.2	8
10 Coated	1600	43.0	48.5	7
11		43.5	49.0	8
12		43.0	50.0	8
Average		43.2	49.2	7.6

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TABLE 4

BEND TEST DATA OBTAINED ON
ON Cb-752 COLUMBIUM ALLOY

Specimen Number	Test Temp. (°F)	Type Specimen	Remarks
1	1300	Uncoated	120° bend with numerous heavy surface cracks
2			
3			
4	1400		Fractured at a bend angle of 80°
5			
6			
7	1500		120° bend, specimens fractured when taken from test fixture
8			
9			
10	1600		Fractured at a bend angle of 40°
C1	1300	LB-2 coated	120° bend with numerous heavy surface cracks
C2			
C3			
C4	1400		Fractured at a bend angle of 70°
C5			
C6			

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TABLE 5

BEND TEST DATA OBTAINED ON
D-43 COLUMBIUM ALLOY

Specimen Number	Test Temp. (°F)	Type Specimen	Remarks
1	1300	Uncoated	120° bend with numerous heavy surface cracks
2			
3			Fractured at bend angle of 120°
4	1400		Fractured at a bend angle of 100°
5			
6			
7	1600		Fractured at bend angle of 40°
8			
9			
D1	1300	LB-2 coated	Fractured at bend angle of 100°
D2			
D3			
D4	1400		Fractured at bend angle of 70°
D5			
D6			

FIGURE 1 - TYPICAL Cb-752 COLUMBIUM ALLOY TENSILE SPECIMENS AFTER TESTING

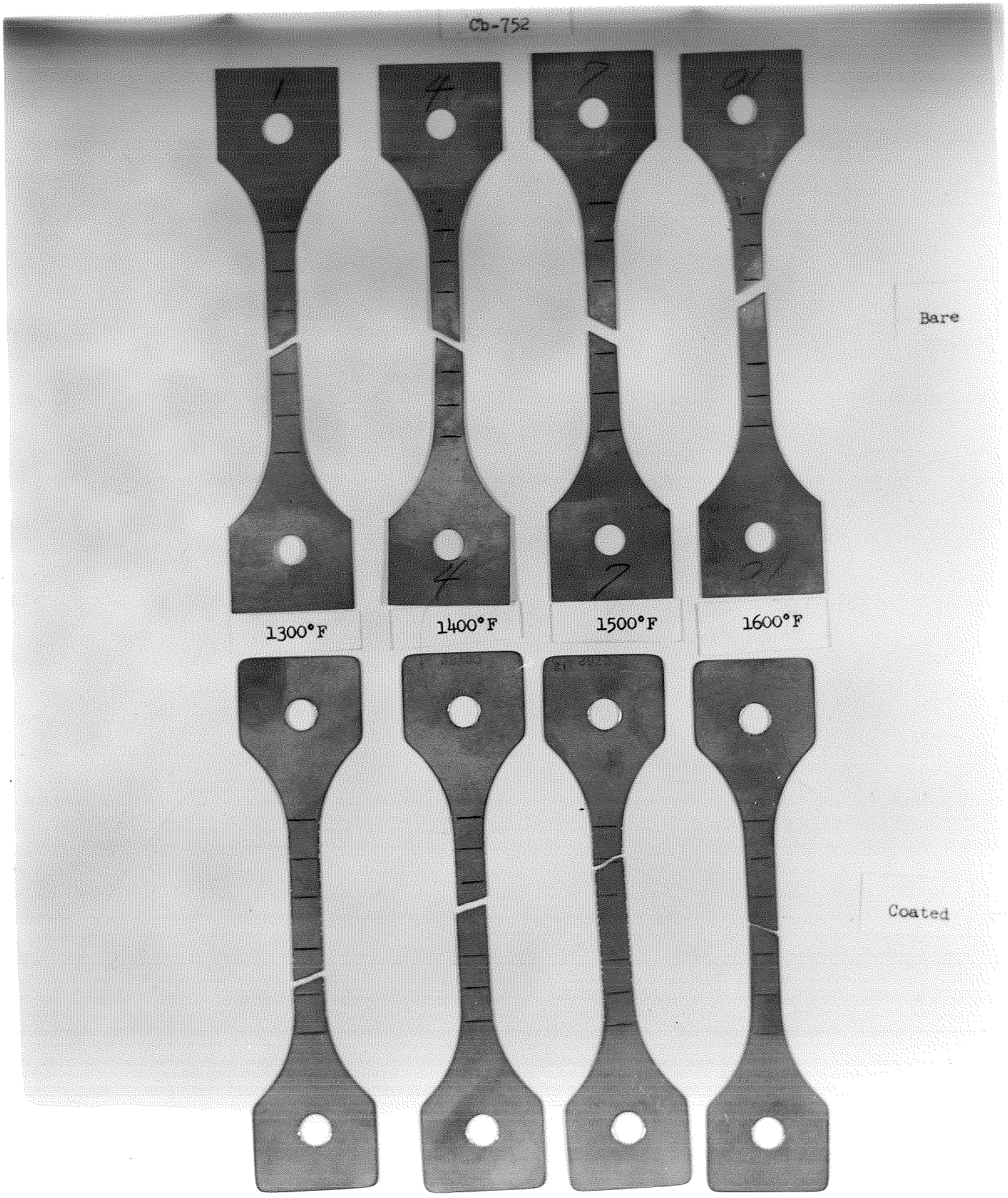

FIGURE 2 - TYPICAL D-43 COLUMBIUM ALLOY TENSILE SPECIMENS AFTER TESTING

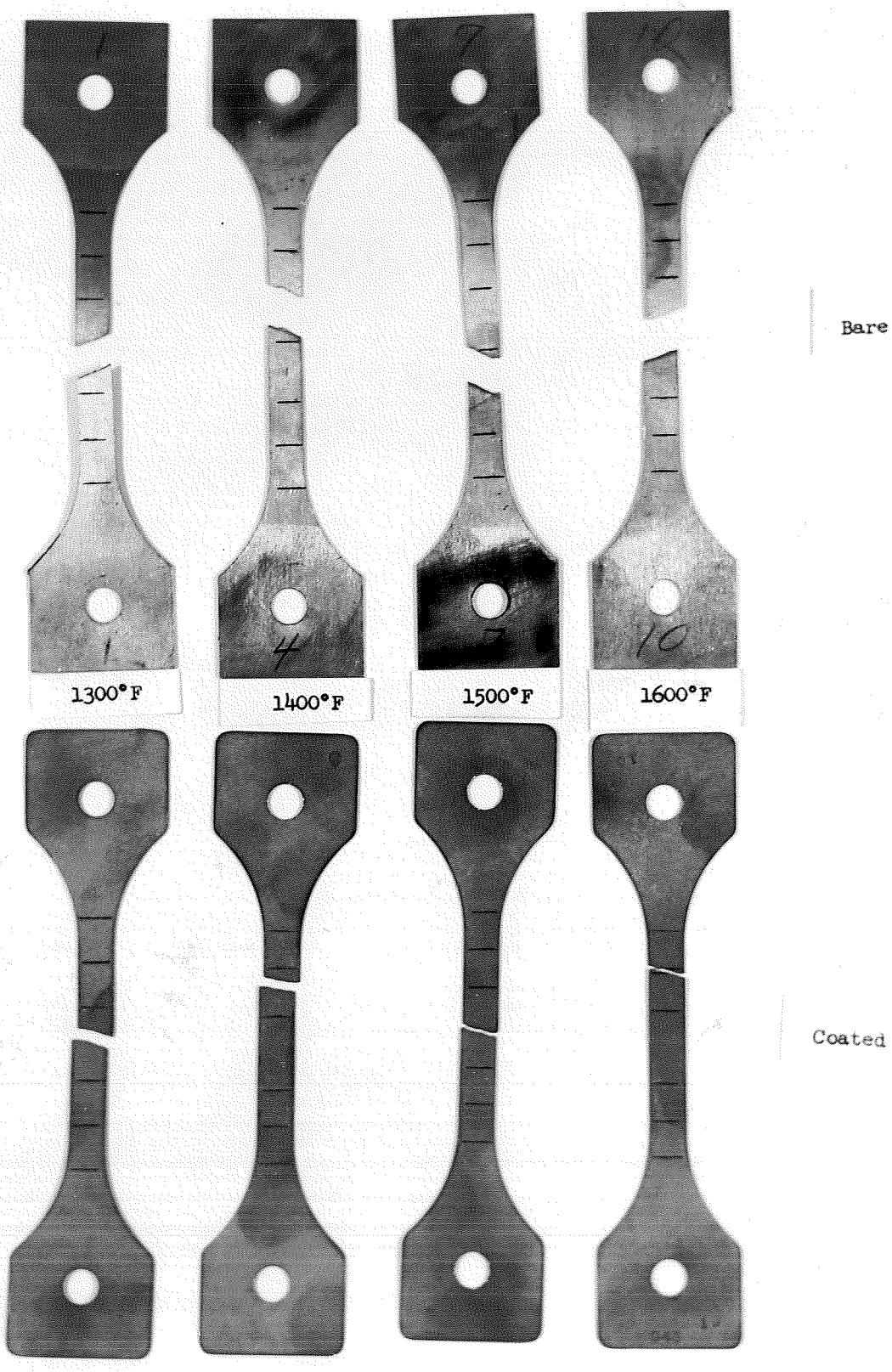

FIGURE 3 - TYPICAL Cb-752 COLUMBIUM ALLOY BEND SPECIMENS AFTER TESTING

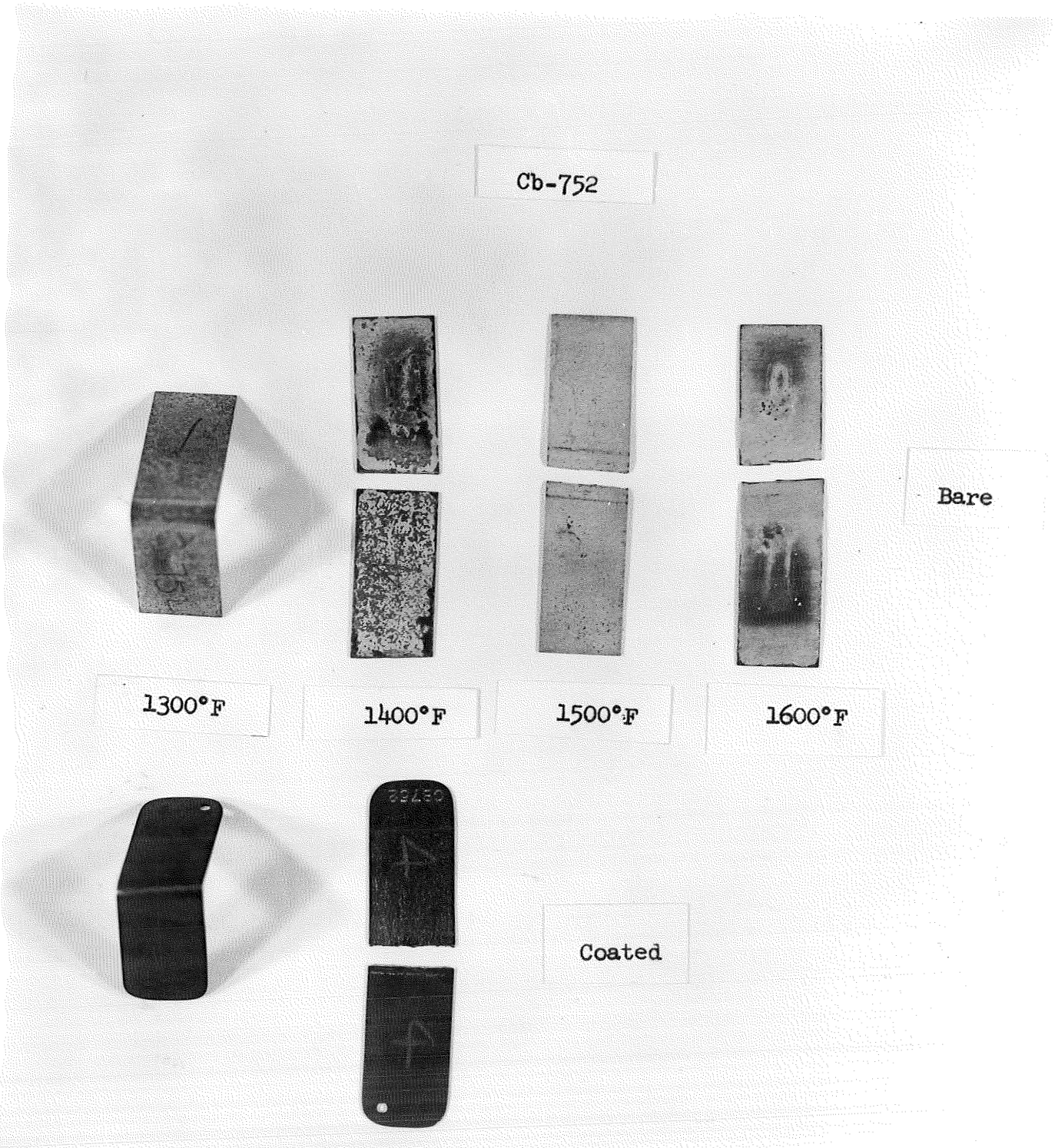

FIGURE 4 - TYPICAL D-43 COLUMBIUM ALLOY BEND SPECIMENS AFTER TESTING

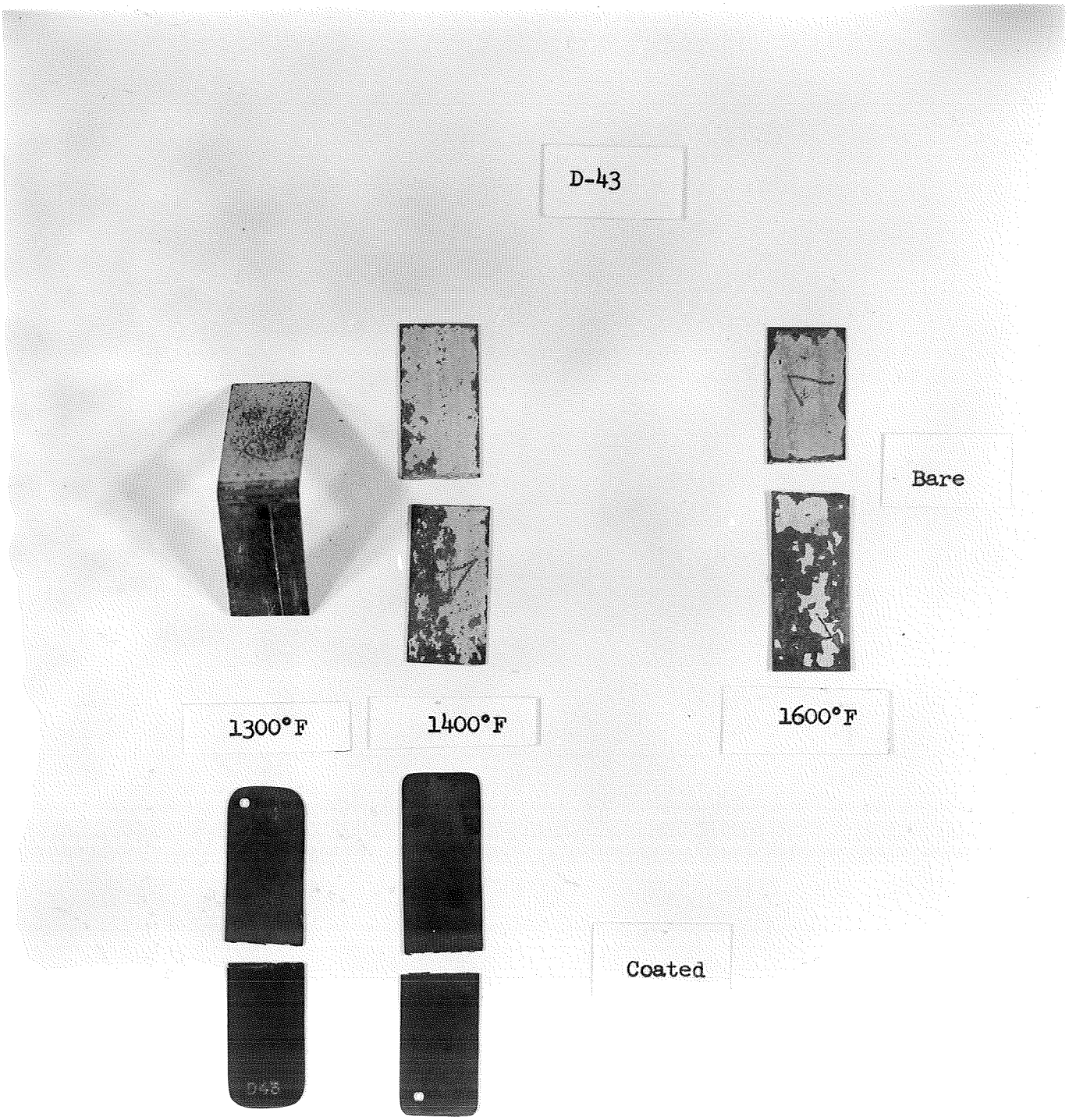

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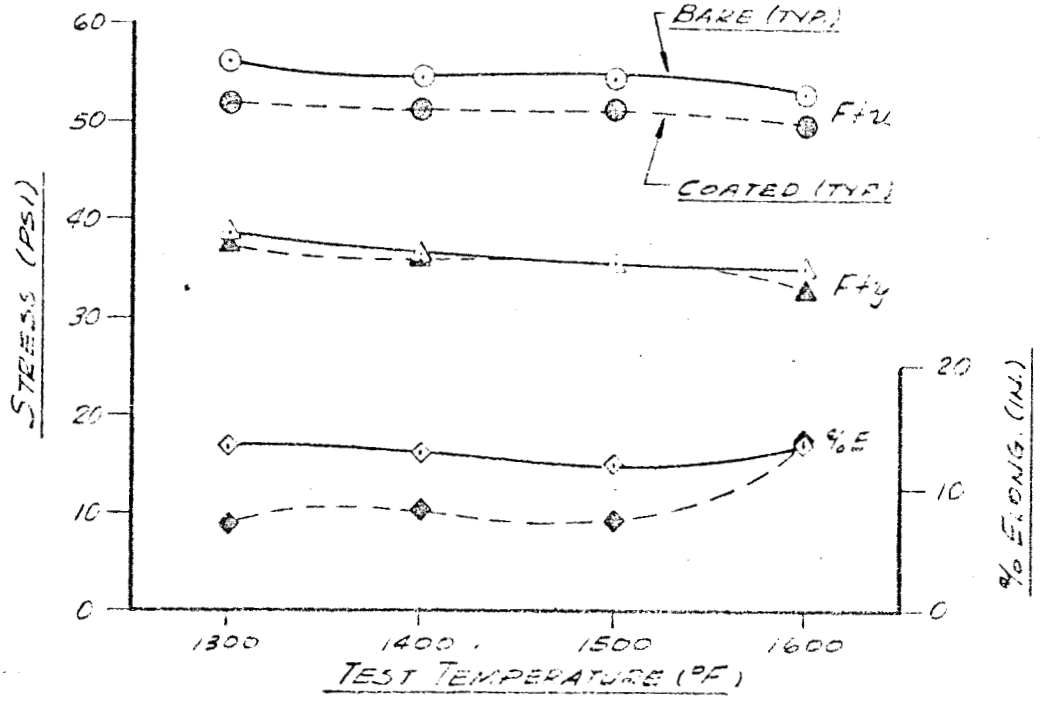
FIGURE 5
AVERAGE MECHANICAL PROPERTIES

Cb 752



D-43